TECHNICAL REPORT NO. 74-07

IMPROVED ELEVATED SITE MARKER

FINAL REPORT

By

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Mobility Branch

DECEMBER 1973

U. S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005

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There has been a continuing need for an efficient position marking device for use by ground units and individuals to mark positions under a heavily forested canopy.

This report presents information on the development of a position marking balloon system for use under a forested canopy. The system consists of: a

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Block 13. ABSTRACT (Continued)

30 inch diameter balloon, 300 feet of tether line, a xenon flashing light, and a 40 cubic inch helium bottle. The total weight of the system is 3-1/2 pounds.

The balloon system was successful as a position marker when winds were below 10 miles per hour. It has a 34 percent calculated probability of being sighted against a daylight jungle background by support aircraft on the first pass over the target area.

The balloon system was also successful as an assembly point marker for airborne troops. Probability of sighting is 100 percent, since airborne troops normally do not operate in winds above 10 miles per hour.

Seven hundred forty (740) balloon position marking systems were prepared for the Marine Corps, but were not delivered. A production flaw was discovered in the helium bottle following a spontaneous rupture of one bottle in a warehouse. Consequently the remaining systems were considered to be unsafe for use.

Seventy (70) balloon position marking systems were informally tested by the 82d Airborne Division and were considered adequate.

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PREFACE

There has been a continuing need for an efficient position marking device for use in heavily forested areas by personnel of all three services. The position marking device must enable personnel on the ground, under a heavily forested canopy, to make known their precise location to friendly and support aircraft overhead. The needs of the three services are similar, but vary according to the function of each. The Naval Air Arm and Air Force require a fast acting, lightweight device that can mark the position of downed airmen for air rescue teams. The Army and Marine Corps depend upon position marking for medical evacuation, resupply and direct fire support and, therefore, require a longer lasting marker. Speed of deployment, while valuable, is not as essential to ground units as for the downed airmen.

The development described in this report is of a system designed for ground units and is not directly applicable to the downed airmen problem.

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INTRODUCTION

Problem

Troops operating under jungle canopies against enemy positions require air support to carry out their mission effectively. Air support may consist of air strikes, insertion and extraction of personnel, medical evacuation, and resupply. Effective support in some of these situations is not possible without the aid of position markers. Conventional markers cannot be used with a visually impenetrable canopy. Also smoke devices and flares are for the most part unsatisfactory due to the screening effect of the canopy, the diffusion of the smoke as it passes through the trees, and their limited duration.

Expedient balloon systems have been tried as position markers on an experimental basis and found to be feasible and to have potential for meeting this requirement. Reference 1 is an account of such a trial by two infantry officers.[1]

Airborne troops have a problem that is similar in one respect to the air support problem above. They also require an elevated marker. The elevated marker is used as a visible assembly point for personnel who have been scattered over a wide area in a drop zone following an air drop.

In the airborne problem, expedient balloon systems had also shown feasibility as assembly aids. Tests at Fort Bragg, NC, showed that assembly time is improved when balloon markers are used.

Brief Description of a Typical Balloon Position Marking System

Basically, a site marker balloon system can be described and may function as follows:

a. Balloon. Lofted through an opening in the forest canopy to a height where it cannot be hidden by adjacent trees. It should be highly visible and have a net static lift of 4 to 5 ounces.

b. Inflation System. Consists of bottled or generated lighter-than-air gases with sufficient buoyancy to permit a 4 to 5 feet per second rate of ascent, which is sufficient velocity to push aside light branches without the balloon becoming hung up.

c. Tether. Usually of nylon, approximately 300 feet long, not weighing more than 0.75 ounces.

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[1] Edmund H. Hornstein, CPT, Inf, and Charles H. Armstrong, CPT, Inf, 14th Infantry Brigade, The Expedient Hydrogen Balloon, Infantry Journal, January 1965.

d. Light. Usually of the flashing type and is attached to the tether 20 to 25 feet below the balloon. It is used for night operations and can be differentiated from campfires, house lights, etc.

These are the essential components of a simple balloon position marker. Many variations are possible. LWL and other Government agencies have investigated and experimented with the basic system described above and its variations. One of the more attractive variations is discussed in "Development of Balloon Systems by Other Government Agencies" which follows.

Background

Goodyear Aerospace Development. The first balloon position marker development undertaken by the Laboratory was accomplished under contract with the Goodyear Aerospace Corporation. This development resulted in a six cubic foot aerodynamic V-balloon, which demonstrated excellent flying characteristics. It maintained an angle of 30 degrees from the vertical in a 30-knot wind. However, it had a complicated bridle and angle of attack compensating system. Its construction was also complicated due to the 12 gores and 3 additional pieces that made up its stabilizing system. Its design was patterned after a larger successful Goodyear design. The design met the contract objectives, but was later adjudged to be too costly for field use. The development was completed in March 1966.

Interim, Quick-Fix Development. The second balloon position marker development was a result of an inquiry and requirement stated by the 5th Special Forces. The inquiry was written with the Goodyear development in mind. The 5th Special Forces wanted essentially an off-the-shelf system for use until a better system became available. The inquiry included suggestions as to the type of balloon system components desired. A CO_2 bottle filled with helium, a weather balloon, and a weather balloon light were among the items mentioned. Quick tests were conducted by LWL to determine if the suggestions could be implemented. It was concluded that a special high pressure bottle for the helium gas would be required to keep the weight of the system to a tolerable level and also a cover to protect the weather balloon from the trees. Also, it was concluded that a better light than that provided by Army meteorological units would be required. LWL responded to the inquiry by delivering 212 systems to the 5th Special Forces and other units in Vietnam. Reports on the effectiveness of the system ranged from enthusiastic to complete rejection. However, there was sufficient interest to warrant an additional request of 200 systems to be distributed to the same units. These were provided. Reports from the 200 units were similar to those above. It was concluded that the unfavorable reports were due mainly to the poor performance of the spherical balloons in winds above 10 MPH.

As a result of the partial success of the Interim, Quick-Fix development, the Marine Corps funded an LWL effort to provide 740 improved balloon systems that became known as the Improved Elevated Site Marker. LWL agreed to provide the 740 systems, with the understanding that the spherical weather balloon - in spite of its poor performance in winds above 10 MPH - would be acceptable for the intended Marine Corps use.

Shortly after the initiation of the task to provide markers for the Marine Corps, the 82d Airborne Division at Fort Bragg, NC, requested that LWL provide them with 70 markers.

Development of Balloon Systems by Other Government Agencies

The Naval Ordnance Station at Indianhead, MD, has developed a sophisticated balloon marking system which is intended primarily to assist air rescue teams in the recovery of downed airmen. The system uses a small rocket to propel a balloon, a gas generator, and a tether package through the trees. The packaging falls away and the balloon begins inflation as it clears the treetops. Inflation is complete at some point below apogee and above the treetops and the gas generator falls away. The balloon is aerodynamic in shape and performs well in winds above 10 MPH. The cost of the Navy system is approximately four times that of the system discussed in this report.

The Navy system is mentioned here because experience with it tends to support the conclusions of this report. Also, the information gained in the Navy development may be useful in future Army developments.

Development of Non-Buoyant Types of Position Markers by LWL and Other Government Agencies

Balloon markers have been considered by some to be too fragile to serve as reliable position markers. The Air Force Measurements Laboratory at Patrick Air Force Base in Florida tested several concepts that depended upon placing a non-buoyant panel type marker on the treetops. These devices were tested at the Jungle Test Center in the Canal Zone during July 1971. LWL was invited to observe and participate in these tests. The devices that were intended to be placed upon the treetops failed in most trials because the methods for placement were inaccurate. Visibility from the ground was obstructed by the canopy so that the devices could not be aimed properly. Also, the canopy was very uneven; so much so that the devices could only be seen when the aircraft was directly overhead. The LWL balloon markers were also demonstrated. In every trial the LWL balloon marker was successful. However, during that time the wind was below 10 MPH, and no problem was encountered with the balloons laying over.

LWL has also developed a non-buoyant position marker that places a smoke signal on the treetops. The LWL system has an effective means for holding the smoke signals on the treetops. These smoke signals were more visible than the passive Air Force systems.

DEVELOPMENT

Design Concept

Expedient Balloon. The need for a device to mark positions under a jungle canopy became known after American troops began to participate in the Vietnam conflict. It was reported that the British and Australian troops used weather balloons extensively during the Malay Campaign. Reference 1 is an account of a field training exercise entitled "Operation Jailbreak", which was conducted in the rain forest on the island Oahu in the State of Hawaii. The following excerpt aptly describes the position marking scenario that is typical of jungle operations:

> "Several months ago the 1st Battalion, 14th Infantry, conducted a field training exercise across the Oahu rain forest, living off the land, and relying on aerial resupply. In the planning stage, it became obvious that aerial resupply would be an immense problem. Drop zones were few and far between. Tropical overcast greatly reduced flight time over the operational area. Clearing drop zones was hard work and resulted in the loss of previous movement time. Expedient methods of ground-to-air signaling were slow to attract the attention of the aircraft. ...Dropping bundles by radio direction - finding was inaccurate. Sometimes it would take hours to recover a bundle dropped a few hundred meters off the mark.
>
> "A signaling expedient had to be devised that could be transported easily by the patrol, prepared rapidly, and which could be identified by the aerial observer. Thus the idea of the field expedient hydrogen balloon was born. If a device could be fabricated to yield hydrogen, the patrol could inflate a balloon, allow it to float above the jungle canopy on a light line and await the bundle drop. Each patrol could be identified by balloons of different colors. ...The best method for signalling is to allow the balloon to rise to an altitude of several hundred feet. Once detected by the aerial observer, the balloon is then reeled into position just above the jungle canopy over the desired drop zone. This compensates for balloon wind drift and ensures pinpoint aerial resupply, even though the aircraft pilot might never see a patrol member or any other DZ marking.
>
> "Another use for the balloon was discovered during the exercise. A small patrol without indirect fire support found a hidden guerilla jungle base. The patrol activated a balloon, gave a compass heading and distance to the target area from the balloon, and radioed for a simulated ordnance and napalm attack. The exercution of the mission was perfect."

The excerpt above, while an idea conceived during a training exercise, points out and clearly shows the characteristics that a good position marker must have:

a. Must be visible to the support aircraft

b. Must be capable of being deployed rapidly

c. Must be light in weight and capable of being carried by ground troops

d. Must be safe to use

In the Introduction, the origin of the requirement is discussed. Comparing the origin of the requirement and the article contained in Reference 1, a fairly clear picture emerges as to what the site marking problem is and as to what the design approach should be. The writers of the 5th Special Forces request and requirement had come close to the design of the system they needed when they referred to a small helium bottle and a weather balloon. LWL had misgivings about going along with a spherical weather balloon. The quick tests referred to in the Background section of the Introduction and presented below reveal the lay-over problems when spherical balloons are used in winds over 10 MPH. A statistical summary of the wind patterns at the Tan Son Nhut Airbase near Saigon (Reference 2) indicates that winds will be between 11 and 16 MPH 25 percent of the time.[2] Thus it can be seen that the reliability of the spherical balloon is reduced during that time. The decision to use spherical balloons was justified on the basis that approximately 75 percent of the time the spherical balloon would be usable. During the time when winds would be above 10 MPH, personnel would, hopefully, become adept in handling the balloon well enough to prevent puncture by adjusting the height to take advantage of wind shielding offered by the close proximity to the treetops, as suggested in the excerpt from Reference 1.

Testing of Off-The-Shelf Components Prior to Development. After the request and requirement was received from the 5th Special Forces, LWL began testing off-the-shelf components procured commercially and items from the DOD supply systems. Items assembled for test were as follows:

a. Meteorological balloons (30 gram and 100 gram) from Army supply system.

b. Off-the-shelf helium bottles from pressure vessel manufacturer.

c. Teardrop shaped balloons from a balloon manufacturer.

d. Lithium hydride (for generating hydrogen gas by reacting with water) from a chemical firm.

e. Air Force survival light (known as SDU-5/E Distress Marker) from Air Force supply system.

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[2]Climatology Division, National Weather Records Service, Statistical Weather Summaries from Data Bank, for Tan Son Nhut, South Vietnam; Bankok, Thailand; Albrook Field, Canal Zone; and Aberdeen Proving Ground, MD, Published by National Weather Service, Asheville, North Carolina, 1972.

f. Meteorological lights for sounding balloons from Army supply system.

g. Assorted sizes of fishing line and stranded nylon line for tethering from sporting goods store.

h. Plastic hydrogen generator bags (made in-house).

The above components were assembled into several different balloon systems and tested against each other and the requirement for marking effectiveness, operational efficiency and cost. The assembled systems were categorized as follows:

Category No.	Description
1-T	Meteorological balloon - High pressure bottle holding 6 Std cu ft of helium gas - meteorological sounding light - 20 pound test fishing line for tether.
2-T	Meteorological balloon - Lithium hydride generator and water - meteorological sounding light - 20 pound test fishing line for tether.
3-T	Teardrop balloon - high pressure bottle holding 6 cu ft of helium gas - Air Force survival light - stranded nylon line 25 pounds breaking strength.
4-T	Teardrop balloon - Lithium hydride generator and water - Air Force survival light - stranded nylon line (25 pounds breaking strength).
5-T	Teardrop balloon - flown in tandem to lift heavier payloads, such as radio and antenna line.

Summary of Tests:

Category No.	Effectiveness	Operational Convenience	Cost of System*	Remarks
1-T	F	G	$ 50	Meteorological balloon limited in visibility - winds forced balloon down - light poor - bottle functioned well.
2-T	F	F	$ 50	Meteorological balloon limited in visibility - winds forced balloon down - light poor - hydrogen generator required 6 quarts of water.

Category No.	Effectiveness	Operational Convenience	Cost of System*	Remarks
3-T	S	G	$150	Teardrop balloon had superior visibility - winds no problem - survival light good - bottle functioned well.
4-T	S	F	$150	Teardrop balloon had superior visibility - winds no problem - survival light good - hydrogen generator required 6 quarts of water.
5-T	S	F	$300	See Note.

S-Superior; G-Good; F-Fair; P-Poor

NOTE: Two teardrop balloons were flown in tandem to lift antenna wire. Extra antenna improved performance of radios.

*Costs were those prevailing in 1966.

Discussion of Tests. The tests shown above indicate categories and not individual tests. Tests were conducted in varying weather conditions: fair and calm, fair and windy, and rain and wind. Tests were conducted in the George Washington National Forest, Shenandoah County, of Northern Virginia.

The 2-T and 4-T balloon systems were hydrogen-filled systems. The weight of the systems, before water was added, was projected to be 1-1/2 and 2 pounds respectively. The lithium hydride required was approximately 1/2 pound for both systems. However, when 12.5 pounds of water was added to each system, the attractiveness of the hydrogen generator as the gas component faded. It was attempted to make the hydrogen generator work with less water. By so doing, the temperature of the reaction was increased to a point where the materials from the generator bubbled up into the balloon. The hot caustic by-products of the reaction weakened the balloon materials and posed a hazard for the operators. Many ratios of lithium hydride to water were tried. Only 1/2 pound of lithium hydride to 6 quarts of water was considered safe and effective.

The teardrop balloons were purchased for the test with a short lead time, consequently, satisfactory coating could not be obtained. The pigment began to flake off upon handling. However, enough adhered to test the visibility of the fluorescent pigments.

The teardrop balloons performed well in the winds, whereas the spherical meteorological balloons were battered against the trees and many were destroyed. When the air was still, the spherical meteorological balloons performed well and would stay up longer than

the teardrop balloons. The teardrop balloons were made from a polyester film known as mylar, normally a very tough and durable film. However, when it was creased, which is necessary in packing, tiny pinholes would appear in the edge of the crease. Balloon manufacturers told us that the only way to prevent the pinholes from forming was to laminate the polyester film with a less brittle film such as polyethelene or polyurethane. This was adjudged to be too costly. Therefore, further testing of the teardrop shaped balloon was abandoned.

The 5th Special Forces had requested an examination of the idea of lofting an antenna system by means of a balloon. It was obvious that one balloon could not lift sufficient antenna to be of use. Thus, the use of two or more balloons in tandem to loft antenna was considered. The idea proved to be workable. It appeared to be best suited to the teardrop shape which generates aerodynamic lift in addition to its static lift. However, it worked for the spherical balloon also.

Comparison of the meteorological sounding light and the Air Force survival light was conducted at the test site. The Air Force light was too heavy for the spherical balloon to loft, so it was necessary to combine it with the teardrop balloon and to fly it on a windy day in order to get it aloft. The sounding light used a water activated battery as its power source. At distances where aircraft could begin to detect the lights (1 to 2 miles in a populated area) the Air Force light was 5 to 10 times more easily detected--based on subjective impressions. The sounding light began to fade after 20 minutes, while the Air Force light was as bright as ever, without noticeable diminishing of the flash rate of one per second. It was concluded that a xenon flashing light of similar circuitry would be required provided the weight could be held under 2.5 ounces.

Various light configurations other than the meteorological sounding light and the Air Force SDU-5/E were tested at the Northern Virginia test site and at the Optical Test Section of Materiel Test Directorate of the Aberdeen Proving Ground. These configurations consisted of various combinations of flashlight bulbs and 1.5 volt batteries. It was attempted to overload a bulb in the hope of getting a very bright light for 10 to 15 minutes. We were successful in achieving some overload for a short period of time, but only for 1 to 2 minutes. None of the configurations compared in brilliance with the Air Force light. The greatest intensity was achieved from .75 to 2.1 candles. The Air Force light measured 7,000 to 12,000 peak candles. Reference 3 points out that the peak flash is not effective in direct proportion to the height of the peak, however, it is effective when the width of the peak reaches or decays to a point where the eye can perceive it.[3] At the test site no optical measuring instruments were available, but subjective impressions showed the Air Force light to be 10 to 20 times more effective. Thus, it was concluded that the cheaper lights of the combinations tested would not be useful.

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[3] Theodore H. Projector, Efficiency of Flashing Lights: Comparison With Steady Burning Lights, Illuminating Engineering, Vol LIV, No. 8, August 1959.

Design of Components

As indicated in Paragraph 3 of the Introduction, the basic or initial design of the balloon marking system came about as a result of an inquiry and stated requirement from the 5th Special Forces. The Marine Corps and the 82d Airborne Division, subsequently having learned of the partial success of the interim or quick-fix system known as the Elevated Site Marker, requested evaluation quantities of the system.

The design and selection of the components that make up the system are discussed below. It was the intent to develop a system from commercially available components or from the Department of Defense supply system as far as possible.

The components selected and developed were assembled into a package that weighed approximately 3.5 pounds and were packaged for carrying in the soldier's combat pack, slung across the shoulder, or on his belt. The operation of the system is detailed in Appendix 1, and shown in Illustration No. 1.

Balloon and Cover. The balloon chosen for this application is the 30 gram size, available through the Army supply system. The following considerations influenced the choice:

(1) Eight Standard Cubic Feet (SCF) of commercial grade helium will lift approximately 8 ounces. The balloon weight is slightly over 1 ounce. The next size available is the 100-gram balloon which is 3.53 ounces. The additional 2.53 ounces would have made the system too sluggish to fly well using 8 SCF of helium.

(2) The 30-gram balloon is designed to hold 6 to 10 cubic feet of gas without over stressing the rubber film. Eight cubic feet of gas was considered to be the best compromise between size, weight, and good visibility.

(3) A plastic film balloon was considered because of its reduced vulnerability to puncture. However, the cost of the plastic balloon would be 30 to 40 times that of the rubber. Plastic balloons would have to be made from gores cut from flat plastic sheets to maintain the desired lift-to-weight ratio of 0.1875. Cutting and assembling of the gores would have been an expensive process, which would not have been consistent with the quick-fix concept that the Marine Corps and 82d Airborne Division were interested in.

(4) The natural color, or white, balloon was chosen from four colors available. The white balloon did not have any added pigments to degrade the elasticity of the rubber. Also, the white appeared to offer the best contrast against the naturally occurring forest green when flown without its cover. It was found through tests that the balloon without its cover would fly well in heavy rain. However, when the cover was added, the water appeared to adhere to the cover in sufficient quantities to weight it down. Tests conducted in the rain chamber at Frankford Arsenal indicated that the bare balloon would maintain its altitude in 4 inches of rain per hour.

Illustration 1. Improved Elevated Site Marker Component Display.

Illustration 2. Improved Elevated Site Marker Deployed.

Illustration 3. Improved Elevated Site Marker Deployed in Wooded Area

Illustration 4. Improved Elevated Site Marker Container.

(5) On the first 412 balloon systems sent to Vietnam, designated as Elevated Site Markers, the balloon was not equipped with a balloon valve. The 740 systems prepared for the Marine Corps and the 70 systems prepared for the 82d Airborne Division were equipped with a balloon valve. The valve reduced the filling time and contributed to the overall reliability of the system. Figure 7 of Appendix 1 shows the location and operation of the valve.

(6) It was found through tests that the unprotected balloon inflated to eight cubic feet would occasionally be punctured through contact with sharp twigs and protrusions on the trees. However, with extreme care, the balloon could be maneuvered through the trees without puncture. Therefore, it was considered necessary to add a cover to protect against this hazard.

(7) The cover was made from 1/2 mil polyester film and coated on both sides with fluorescent pigment. The total thickness after coating was one mil. The cover provided sufficient protection from contact with sharp twigs and protrusions on the trees.

(8) The coating on both sides provided the option of displaying two different colors for the purpose of added flexibility in signalling. The fluorescent pigment in the coating has the ability to convert the light energy of the ultraviolet and blue end of the spectrum to light energy of visible longer wave lengths, thereby appearing to radiate energy on its own or being self luminous. Further discussion on how the color aids visibility is given in paragraph 4, Visibility and Detection.

(9) The balloon is confined within the shroud lines of the cover as shown in Figure 9, Appendix 1, and as shown in Illustration No. 2. Provisions were made in the system so that the balloon can be flown without the cover. See Figure 8 and paragraph 7 of Appendix 1. The total weight of the cover is 1.6 ounces.

b. Tether. The tether selected was monofilament nylon fishing line manufactured by DuPont. It was chosen because it provided greater visibility than other tethers which allowed the pilot and crew of the support aircraft to see more clearly the tether point or the canopy opening. The monofilament line demonstrated less tendency to snag than stranded lines.

The length of 300 feet provides the advantage of clearing the tallest trees, see Illustration No. 3. Additional height, provided by the 300-foot length, gives the impression of movement to an otherwise stationary balloon when viewed by a moving aircraft. This effect is similar to that experienced by viewing utility poles when traveling along a highway. Poles appear to move, but the backdrop appears stationary. This effect enhances the detectability of the balloon when the air is still.

c. Flashing Light. The Blondel-Rey computation of the relationship of steady lights to flashing lights indicates that a flashing light is 5 times more effective than the light of a steady light of the same intensity. This determination was made at visual threshold ranges, Reference 2. This phenomenon is obvious, in a nonquantitative way,

to everyone who has observed aircraft flying at night or emergency vehicles on the highway. At ranges less than the threshold range, the ratio may be greater than 5 to 1. However, this is difficult to determine since it depends upon psychological and physiological factors that have yet to be analyzed.

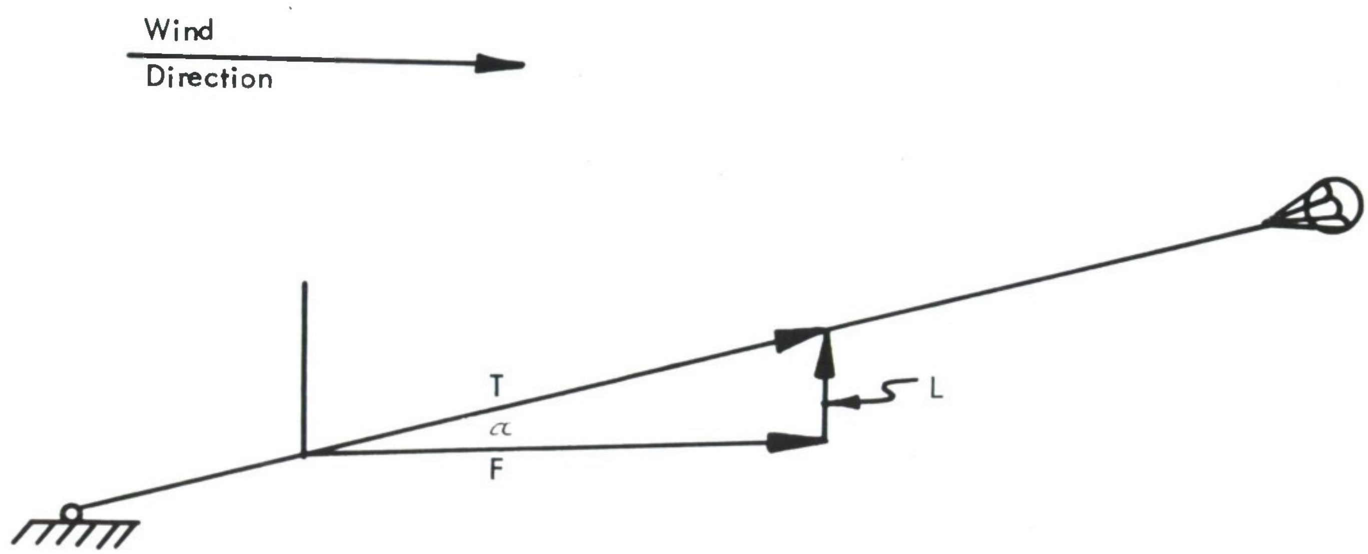
From a purely energy expended point of view, it has been found that the flashing light's efficiency can be 20 times that of steady light. Steady lights were examined first in an attempt to keep the cost of the balloon system down. However, it became evident that steady lights would not be adequate, particularly where other competing lights would be confusing to the observer.

The flashing light developed was patterned after the Air Force SDU-5/E Light, Distress Marker, FSN 6230-067-5209. LWL selected one of the manufacturers of the Air Force light and asked them to strip it down in weight to the lowest practicable level. The resulting light weighed approximately 2.3 ounces, flashed 30 to 45 flashes per minute, had 2.0 overall effective candle power, and had a peak instantaneous output per flash of 12,000 candle power. The light could maintain its intensity and flash rate of 1/2 hour and then began to decay to slightly less than peak intensity and a flash rate of 10 to 15 flashes per minute after 8 hours. The effective life was considered to be 4 hours, with a flash rate of 20 to 30 flashes per minute and a barely discernible decrease in peak intensity.

In actual operation, the light is tied to the tether approximately 15 to 20 feet below the balloon, with the flashing end pointed upward. Tests at the Aberdeen Proving Ground, MD, showed that the flashing light is visible for at least 1-2/3 miles during the first 30 minutes of its operational life, and has frequently been sighted at ranges up to 5 miles.

d. <u>Helium Bottle</u>. The 5th Special Forces request for a small helium bottle approximating the size of a life raft CO_2 bottle which was 8 inches long and 2-1/2 inches in diameter was given serious consideration. To accomplish the purposes that the 5th Special Forces were seeking to do, the balloon would have to contain at least 8 cubic feet of helium gas. Further, to maintain the weight of the balloon system within the bounds implied by the 5th Special Forces request, and to maintain what was considered to be an optimum size for a system with the required performance (see Illustration No. 4), it was necessary to design a helium bottle to the following specifications:

Volume capacity	8.9 Standard cubic feet of helium (at standard conditions)
Total weight	2.5 pounds
Size of bottle	40 cubic inches, 2.89 inches diameter x 8.75 inches long
Service pressure (Working pressure)	6,800 PSI
Test pressure	10,200 PSI
Burst pressure	13,600 PSI



$$\tan \alpha = \frac{L}{F} = \frac{2}{25.91}$$

$$\alpha = 4.41°$$

L = Lift = 2 Ounces

F = Aerodynamic = 25.91 Ounces

T = Tether Line Tension = 25.99 Ounces

α = Angle of Tether with Horizontal

Illustration 5. Force Diagram at 10 MPH

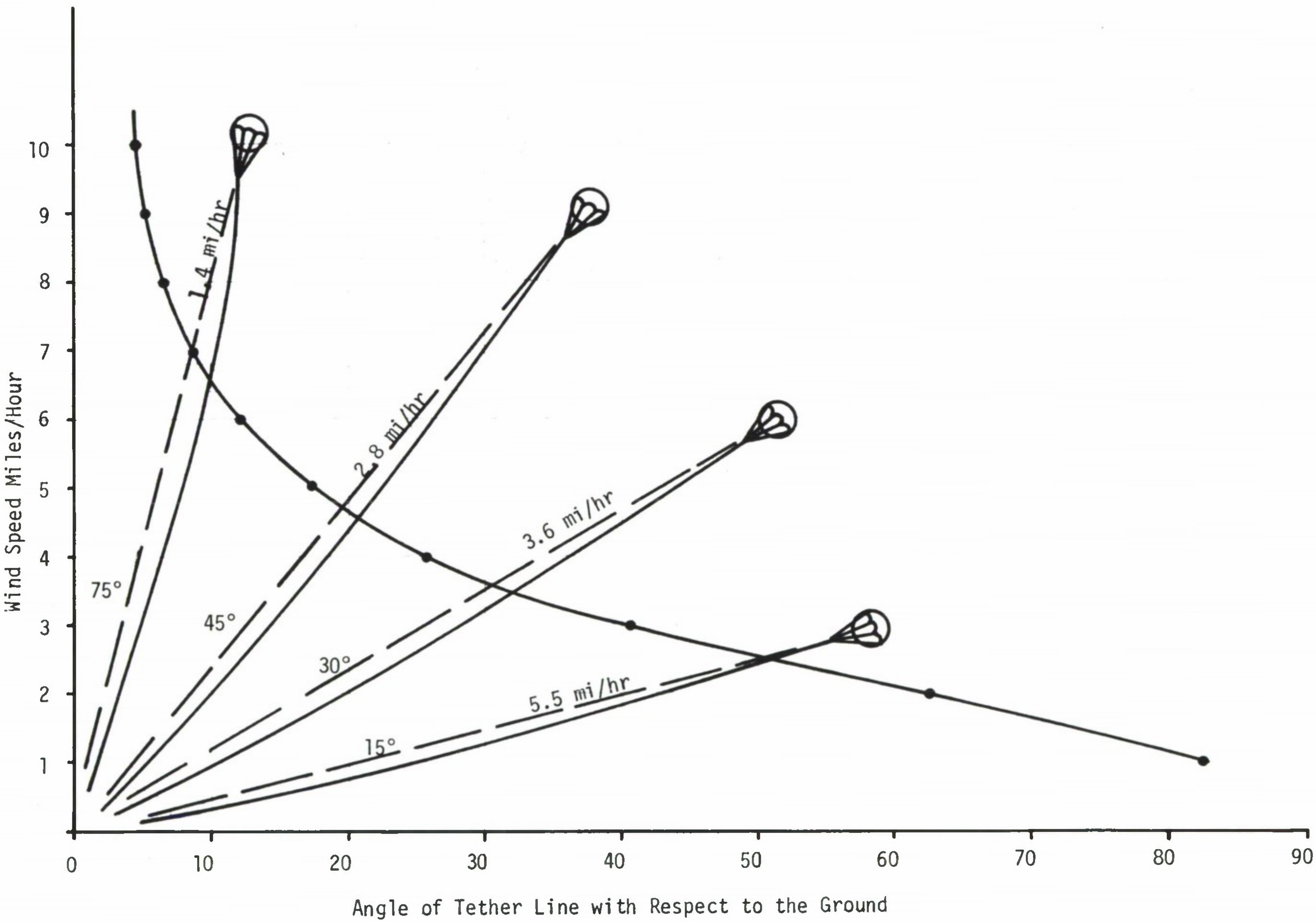


Illustration 6. Balloon Performance at Varying Wind Speeds

These specifications could not be met under normal commercial pressure vessel design and manufacturing processes. However, aerospace pressure vessel technology permitted higher pressures without creating undue hazards. The Interstate Commerce Commission (ICC), now Department of Transportation (DOT), issued a Special Permit No. 4645 for transporting the bottle on common carriers under a green label.

The bottle was fitted with a stainless steel needle and brass valve seat. One-half turn of the valve was sufficient to empty the contents of the bottle into the balloon in approximately 5 seconds.

The bottle was tested at the contractor's plant in accordance with the then existing ICC regulations for nonstandard high pressure vessels. The bottle was also tested at Aberdeen Proving Ground. Results of these tests are given in paragraph 5, Testing, and Appendix A.

The leak rate of helium from a properly functioning bottle, given by the contractor, is 5.5×10^{-6} cubic centimeters per second. At this rate the loss would be 0.0765 of 1 percent a year, a negligible amount.

Aerodynamic Considerations

As mentioned previously, there were misgivings about providing a site marking system with a spherical balloon. The analysis below provides the reason for the poor performance:

$$F = 0.2591{*}V^2$$

F = Aerodynamic force in ounces acting on the balloon
V = Wind speed in miles per hour
* See Appendix C for derivation of constant

There are only approximately two ounces of free lift, due to buoyancy, acting to keep the balloon aloft. The force diagram is shown in Illustration No. 5. A plot of the balloon's calculated performance versus wind speeds is shown in Illustration No. 6. As indicated, wind speeds at approximately 5 MPH cause the balloon tether to assume an angle of 15 degrees with respect to the ground. At 10 MPH the balloon is only 4.41 degrees with respect to the ground.

Fortunately, the balloon performance is not quite as bad as the calculations indicate. Winds in close proximity to the ground occur in gusts. Winds gusting to 10 MPH have an average wind velocity of 5 to 7 MPH. The balloon cannot respond quickly to each gust--due to aerodynamic drag and inertia effects and tends to oscillate about an angle corresponding to the average wind speed.

Winds under a jungle canopy are only a fraction of those above. Thus, it is usually no problem in getting the balloon up through the canopy. After the balloon is above the

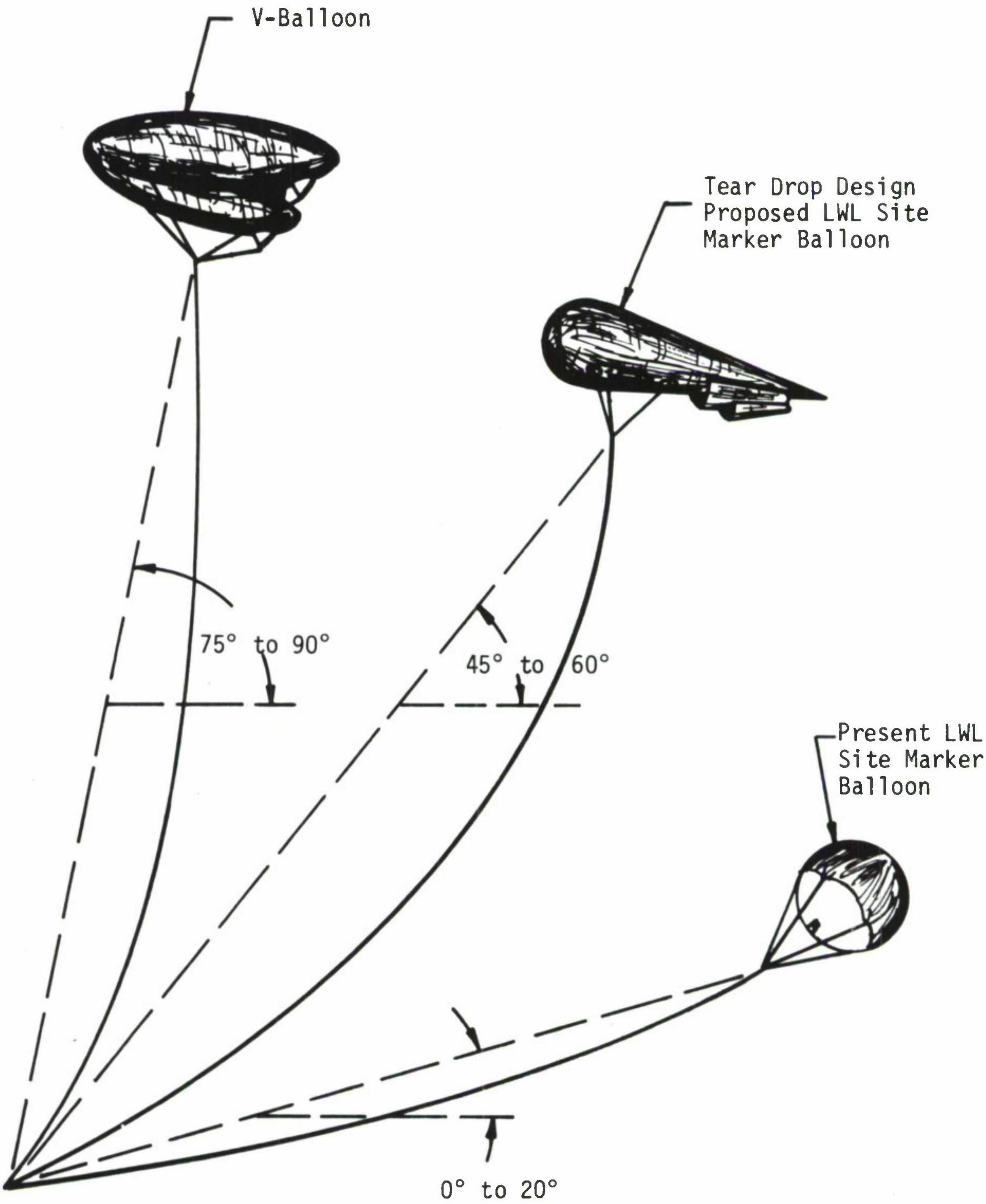


Illustration 7. Balloon Designs at 10 MPH

treetops, it responds to the wind as predicted. Winds above 10 MPH batter the balloon against the treetops. Visibility is seriously reduced and the balloon is likely to be punctured.

The question that comes to mind is: how often do winds above 10 MPH occur? At lower elevations (sea level), winds above 10 MPH occur 20 percent of the time. Winds above 10 MPH at higher elevations (3500 ft) occur 30 percent of the time. These generalizations were obtained from Reference 2.[4] During periods of seasonal changes, the frequency of higher winds in the Monsoon season in Southeast Asia increases. Winds may exceed 10 MPH every day.

It would appear that the unfavorably response of the spherical balloon to winds over 10 MPH would warrant changing the balloon shape to one of those that responds more favorably to the wind now that materials without the pin hole problem are available at reasonable cost. For example, in Illustration No. 7 the V-balloon design remains virtually unaffected by winds at 10 MPH. The teardrop design responds almost as well. Although the cost of these designs may be many times that of the spherical balloon, it appears that the cost is justified on the basis of increased reliability.

Visibility and Detection

The balloon must be highly visible and detectable to be worth the cost and effort to deploy it. How visible and detectable it must be to be cost effective will not be known until sufficient experience has been gained in the field. There is no question that its need is great in situations where other position markers do not work. As mentioned before, the Army, Navy and Air Force have attempted to develop a workable system. The Australians have found simple expedient systems useful, but not entirely satisfactory. Therefore, some method of measuring and predicting site marking efficiency by balloons is required.

A study prepared by the Human Sciences Research, Inc., titled Development of an Air to Ground Detection/Identification Model (Reference 4), appears to offer the best method of obtaining a measure of the efficiency of balloon site marking systems.[5] Also, the model appears to be suitable for evaluating other site marking systems as well. A direct quote from the study defines and summarizes the study and the model capabilities.

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[4]Climatology Division, National Weather Records Service, Statistical Weather Summaries from Data Bank, for Tan Son Nhut, South Vietnam; Bankok, Thailand; Albrook Field, Canal Zone; and Aberdeen Proving Ground, MD, Published by National Weather Service, Asheville, North Carolina, 1972.

[5]Margaret E. Franklin and John A. Wittenburg, Human Sciences Research, Inc., McLean, Virginia, Development of an Air-To-Ground Detection/Identification Model, Prepared for: U. S. Army Human Engineering Laboratories, Aberdeen Proving Ground, MD, 1965.

"The objective of the research was to develop a model for the prediction of target detection/identification probabilities. The intended scope of the model was limited to include only unaided visual air to ground observation of tactical targets by trained observers. It was further limited to cover the following range of conditions:

Altitudes	Nap of the earth to 3000 feet
Speed	Hover to 350 MPH
Illumination	Daylight (morning twilight to evening twilight)
Visibility	Clear

The model scenario was devised with the detection of tactical targets that are always painted with a neutral olive drab to prevent or minimize detection. The model was also limited to altitudes under 3000 feet. In these respects the model scenario differed with that of the balloon detection scenario. The balloon with its cover is highly visible, offering nearly maximum contrast with the forest-green background. Tests at Aberdeen Proving Ground indicated that the balloon and cover is visible for well over a mile. To use the model effectively, it was necessary to extend the altitude to exceed 3000 feet and extend the contrast factor to 24. The mathematical and physical parameter constraints were studied to determine whether the logic of the model would be violated if the altitude extensions and color contrast adjustments were made. It was concluded that these adjustments could be made without error.

One may wonder why it is necessary to calculate the probability of sighting a target as visible as the balloon. It could be conjectured that if a bright object is out in front, one would surely see it. However, after a review of the physiology of the human eye, it becomes evident that a bright object being in the field of view is no assurance of seeing it. Only a very small portion of the eye is capable of resolving and identifying an object within our view. The memory and integrating capacity of the brain make us feel as though we are seeing a wide panarama at one instant in time. The portion of the eye that really does the seeing is the fovea. If it were possible to project the fovea through the lens of the eye, and compare it with the panorama, the fovea would appear small indeed. The resolving portion of the fovea subtends a solid angle in the panoramic or binocular sphere of only .000239 steradians as compared with 1.46 steradians subtended by the total binocular field. This amounts to 0.016 thousands of one percent (or .0001636 of the total binocular field). Just how small it is can be sensed by fixing the eyes on a point and attempting to read or identify an object slightly off our visual axis or the point of fixation. Realistically, it can be compared to being in a darkened room with a flashlight with a very narrow beam. To find what we are looking for, it is necessary to systematically scan the area with a flashlight.

This is the problem that search and identification training of air crew members seeks to solve. How well they solve it is given by the mathematical model referred to above.

The detailed calculations involved in the use of the model are included in Appendix D. Results of the calculations are presented in the conclusions and Appendix D.

Results of the calculations were confirmed by the limited tests performed at Aberdeen Proving Ground. Also, the effort expended in coloring the balloon cover is justified.

Testing and Evaluation

a. Engineer Design Test of Site Marker Balloon (Interim or Quick-Fix System). Prior to shipping the Site Marker Balloons to users in South Vietnam, the system was tested at Aberdeen Proving Ground by the U.S. Army Test and Evaluation Command. The purpose of the tests was to obtain an independent agency assessment of the merits and demerits of the system, and secondly, to obtain a safety statement regarding the existence of undue hazards. Elements of the tests included the following:

(1) Operational checks of system and applicability of instruction sheet.

(2) Drop tests on helium bottle.

(a) Drop on valve end from 40 feet.

(b) Drop on opposite of valve end from 40 feet.

(c) Drop on side from 40 feet.

(3) Cold temperature cycling from ambient to -65 degrees F, and repeat test above from a distance of 20 feet.

(4) Gunfire tests from a protective bunker with 30 caliber ball ammunition fired into packaged systems.

Results of the tests were as follows:

(1) System performed well in winds below 10 MPH. Performance was poor in winds above 10 MPH.

(2) Bottles maintained structural integrity on all drops from 40 feet. Leaks developed when dropped on valve end. Leaks appeared to result from "coining" of the brass needle-valve, and could be stopped by retightening the valve by hand.

(3) Bottles maintained structural integrity on all cold temperature drops. No cold temperature damage was detected.

(4) Bottles exploded violently when struck by ball ammunition at close range. Bottle ruptured into 3 to 4 large fragments. Some fragments penetrated a one inch plywood board on which they were mounted. This was not surprising since each bottle contains 22,600 foot pounds of energy.

The conclusions of the USATECOM test report were as follows:

(1) The test item can be operated, transported and stored safely when normal precautions exercised for pressurized containers are adhered to.

(2) The charged helium cylinder constitutes a hazard in that the cylinder will explode into fragments when hit by small arms fire and as a result could seriously injure or kill nearby personnel.

(3) Cylinder may develop a leak if dropped on the valve end.

The USATECOM tests showed the following shortcomings:

(1) The lengthy deployment time of 5 to 10 minutes.

(2) Poor performance in winds above 10 MPH.

(3) Vulnerability of helium bottle to small arms fire.

b. User Evaluation in South Vietnam as Reported by ACTIV (Army Concept Team in Vietnam). Originally the 212 Site Marker Balloons were earmarked for the 5th Special Forces. However, as the requirement for a jungle canopy site marker began to intensify, other units began to request the systems for evaluation. Consequently, the decision was made to parcel out the 212 systems to the requesting units. Unfortunately, most of the 212 systems were either lost in the supply system or used without reporting. Only 17 systems were available for evaluation. These were distributed to the 25th Infantry Division, 173d Airborne Brigade and the 5th Special Forces Group.

The evaluations performed on the 17 systems were considered inconclusive by ACTIV. Therefore, an additional 200 systems were requested. The essence of the ACTIV evaluation was very similar to the USATECOM evaluation above. There were some comments on the questionnaires that indicated a lack of indoctrination on the part of the test personnel. The writer of the ACTIV test report apparently did not quite understand the purpose of the marker. One statement in the conclusions of the report said that the balloon marker did not compare favorably with panel markers, smoke and flares. Obviously, if the panel markers, smoke and flares were being used successfully, there was no need for a balloon marker. Reports are cited in References 11 and 12.[6]

c. Testing of the Improved Elevated Site Marker by the 82d Airborne Division. The Improved Elevated Site Marker is a modification of the system evaluated by ACTIV. Modifications and/or differences are as follows:

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[6] U. S. Army Test and Evaluation Command, Aberdeen Proving Ground, MD, Engineer Design Test of Site Marker Balloon, USATECOM, 1966.

(1) Balloon is equipped with a check valve to speed the inflation process. The valve prevents the gas from escaping and eliminates the necessity of tying off the balloon after filling. See Appendix 1, Figures 6 and 7, paragraphs 5 and 6.

(2) Cover was modified by changing from rip stop nylon cloth to a polyester film mylar cover. The mylar cover provides some additional protection from puncture.

(3) In the system evaluated by ACTIV, four separate balloons and four separate covers were supplied to provide flexibility in signalling. However, in order to reduce the weight, cost and complexity of the system, only one reversible cover was provided on the improved system. The colors were orange on one side and green on the other.

(4) Other marginal improvements were made to the packaging and instruction sheet.

Tests conducted by the 82d Airborne Division found that the system was suitable for marking drop zones. The lay-over problem was not a matter of concern to them since air drops do not normally occur in winds above 10 MPH. The Improved Elevated Site Marker package did not hinder the parachutist. They stipulated that the package should not be worn over the kidney area.

The 740 systems scheduled for evaluation by the Marine Corps could not be evaluated because of a production flaw discovered in the helium bottles.

CONCLUSIONS

a. The Improved Elevated Site Marker is effective in marking sites under canopied forests in low wind conditions. Under high wind conditions (10 to 30 MPH), its effectiveness is drastically reduced. Its sighting probability under low wind conditions is approximately 35 percent on the first pass of the support aircraft. Under high wind conditions its sighting probability is much lower.

b. The Improved Elevated Site Marker is effective as an assembly point marker for airborne troops. No probability of sighting is assigned, but it can be assumed to be 100 percent under forseeable conditions.

c. The balloon, although protected by a cover, is subject to puncture under some operating conditions. The helium bottle is hazardous to personnel when exposed to small arms fire. However, the helium bottle is safe for use when exposure to small arms fire is not present.

d. A site marking system shown in Illustration No. 7 is currently under development at USALWL. A sighting probability of 45 percent (calculated) on the first pass of the support aircraft appears to be attainable. The increased visibility is due to the larger size. Increased reliability is expected from the use of a more durable balloon fabric and from good performance in high winds.

REFERENCES

1. Edmund H. Hornstein, CPT, Inf., and Charles H. Armstrong, CPT, Inf., 14th Infantry Brigade, The Expedient Hydrogen Balloon, Infantry Journal, January 1965.

2. Climatology Division, National Weather Records Service, Statistical Weather Summaries from Data Bank, for Tan Son Nhut, South Vietnam; Bankok, Thailand; Albrook Field, Canal Zone; and Aberdeen Proving Ground, MD, Published by National Weather Service, Asheville, North Carolina, 1972.

3. Theodore H. Projector, Efficiency of Flashing Lights: Comparison With Steady Burning Lights, Illuminating Engineering, Vol LIV, No. 8, August 1959.

4. Margaret E. Franklin and John A. Wittenburg, Human Sciences Research, Inc., McLean, Virginia, Development of an Air-To-Ground Detection/Identification Model, Prepared for: U. S. Army Human Engineering Laboratories, Aberdeen Proving Ground, MD, 1965.

5. Sighard F. Hoerner, Dr. - Ing. Fluid-Dynamic Drag (Theoretical, Experimental and Statistical Information), Published by the Author, 1958.

6. Fluid Motion Panel of The Aeronautical Research Committee, Edited by Sydney Goldstein, Prof. Applied Mathematics, Harvard University, Modern Developments in Fluid Dynamics, Volumes 1 and 2, Dover Publications, Inc., 1965.

7. Charles S. Williams and Orville A. Becklund, Texas Instruments, Inc., Optics: A Short Course for Engineers and Scientists, Wiley-Interscience, Division of John Wiley & Sons, 1972.

8. Joint Army-Navy-Air Force Steering Committee, Editors: Clifford T. Morgan, Jesse S. Cook III, Alphonse Chapanis and Max W. Lund, Human Engineering Guide to Equipment Design, McGraw-Hill Book Company, 1962.

9. Department of the Army, Army Concept Team in Vietnam, Elevated Site Marker Balloon (ACL 35/68M), Army Concept Team in Vietnam (ACTIV), 1968.

10. Department of the Army, Army Concept Team in Vietnam, Elevated Site Marker Balloon (ACL 89/67), Letter Report, Army Concept Team in Vietnam (ACTIV), 1967.

11. U. S. Army Test and Evaluation Command, Aberdeen Proving Ground, MD, Engineer Design Test of Site Marker Balloon, USATECOM, 1966.

12. S. W. Akin, The Thermodynamic Properties of Helium, ASME Paper 49-A-96, Transactions of American Society of Mechanical Engineers, November 1949.

BIBLIOGRAPHY

1. Charles A. Douglas, Computation of the Effective Intensity of Flashing Lights, Illuminating Engineering, Vol 52, No. 12, December 1957.

2. Theodore H. Projector, The Role of Exterior Lights in Mid-Air Collision Prevention, Final Report No. 4, Project No. 110-512R, Prepared for the FAA by Applied Psychology Corporation, July 1962.

APPENDIX A

Helium Bottle

Calculation of size of helium to hold 8 standard cubic feet of helium supplied by contractor.

Reference 12 states that helium does not obey the classic or general law for an ideal gas.[7]

V_c = Volume of cylinder ft^3

V_b = Volume of balloon ft^3

v_c = Specific volume of helium before inflation

v_f = Specific volume of helium after inflation

$$\frac{V_c}{v_c} = \frac{V_c + V_b}{v_f} \quad \text{Conservation of mass}$$

Using van der Waal's equation of state and Akins pseudo critical constant B_o and modified gas constant R^1;

then $\quad v_c = \frac{R^1 T}{P} + B_o$;

where $\quad B_o = 0.3059T^{-1/4} - 1.84T^{-3/4} - 0.822T^{-5/4} = 0.0469\ ft^3/lb$.

T = 530° Rankine (R).

p = Approximate bottle pressure = 6815 psi.

$$v_c = \frac{2.6829 \times 530}{6815} + 0.0469 = 0.2554\ ft^3/lb\ .$$

At 1 inch of H_2O at 560° R;

v_f = $102.2\ ft^3/lb$;

---

[7] S. W. Akin, The Thermodynamic Properties of Helium, ASME Paper 49-A-96, Transactions of American Society of Mechanical Engineers, November, 1949.

then at 1 inch of H_2O at 530° R, therefore

$$v_f = 102.2 \times \frac{530}{560} = 96.9 \ \text{ft}^3/\text{lb}$$

$$\frac{V_c}{v_c} = \frac{V_c}{0.2554} = 3.92\ V_c$$

$$\frac{V_c + V_b}{v_f} = \frac{V_c + 8.0}{96.9} = 0.01032\ (V_c + 8.0)$$

Therefore $$V_c = \frac{0.01032 \times 8.0}{3.92 - 0.01} = 0.02117\ \text{ft}^3 = \underline{\underline{36.6\ \text{in}^3}}$$

Round off to 40 in^3 for possible changes in filling conditions.

Calculations to check on manufacturer's bottle dimensions

Using the ASME Code (Barlow formula modified by Boardman)

t = minimum wall thickness

P = proof test pressure = 10,200 psi

R = inside radius in inches = $\frac{2.89}{2}$

S = working stress for chrome molybdenum AISI 4130 Steel = 200,000 psi

$$t = \frac{PR}{S - 0.6P} = \frac{10{,}200\left(\frac{2.89}{2}\right)}{200{,}000 - 0.6\ (10{,}200)} = 0.076 \text{ inches}$$

Manufacturer's bottle wall thickness measured 0.090 inches, which allowed a proof test pressure of 12,500 psi and a burst pressure of 15,500 to 16,500 psi.

APPENDIX B
Improved Elevated Site Marker Operating Instructions

INSTRUCTIONS FOR INFLATING AND LOFTING THE SITE MARKER BALLOON

WARNING BOTTLE WILL RUPTURE EXPLOSIVELY IF STRUCK BY SMALL ARMS FIRE OR OTHER HIGH VELOCITY OBJECTS

READ INSTRUCTIONS THROUGH CAREFULLY BEFORE ATTEMPTING TO OPERATE SITE MARKER

1. REMOVE CONTENTS from system container (1) balloon-helium-bottle tether assembly, (2) reversible balloon cover, (3) flashing light. REMOVE CAP from (balloon-bottle-tether) assembly by removing sealing tape. FIG 1

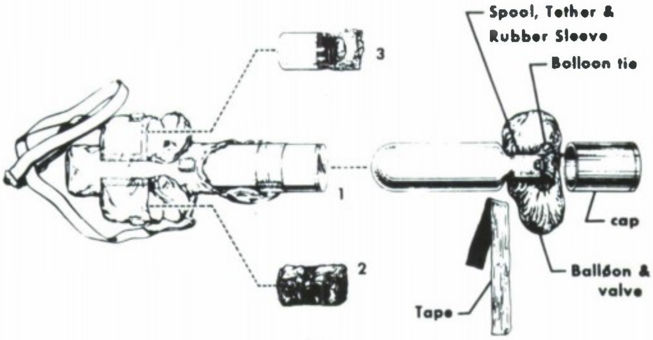

FIG 1

2. REVERSE COVER TO CHANGE COLOR IF NECESSARY. FIG 2

FIG 2

3. ATTACH TETHER LINE. FIG 3 & FIG 4

4. PLACE COVER OVER BALLOON. Bottle should remain partially in carrying case, since it becomes cold during inflation. POINT BOTTLE AWAY FROM OPERATOR , TO INFLATE BALLOON TURN TOP OF BALLOON TETHER ASSEMBLY AS INDICATED IN FIG 5. FOR QUIET AND SLOWER INFLATION OPEN VALVE SLIGHTLY, FIG 4 & FIG 5. Use all of helium in bottle.

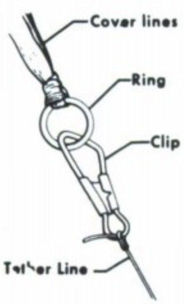

FIG 3

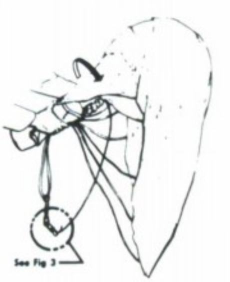

FIG 4

FIG 5

5. **DETACH BALLOON FROM BOTTLE FIG 6, lift "O" ring and pull away from bottle.**

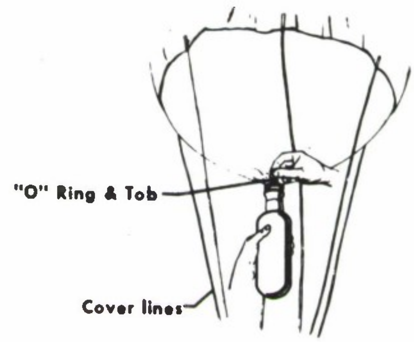

FIG 6

6. **SEAL BALLOON VALVE** by a light pull on poppet. FIG 7
7. If rain is likely, omit cover. Bare balloon will fly in medium to heavy rain. **ATTACH TETHER TO BALLOON** as shown by FIG 8. Draw balloon tie sufficiently tight to prevent valve from slipping thru it.
8. **LOFT BALLOON.** Select best available canopy opening. Allow for wind by positioning operator accordingly. Operator can maneuver the balloon thru relatively small openings by varying lofting velocity. FIG 9

FIG 7

FIG 8

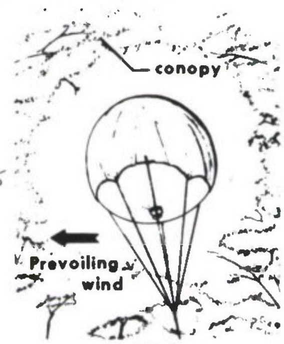

FIG 9

9. **FOR NIGHT USE, ATTACH FLASHING LIGHT FIG 10** approximately fifteen to twenty feet below balloon. **ACTIVATE** by twisting leads together.
10. **SECURE TETHER LINE** to any convenient ground object. FIG 11

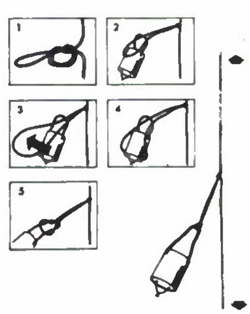

FIG 10

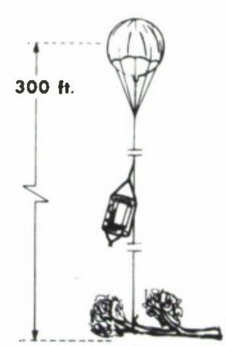

FIG 11

APPENDIX C

Aerodynamic Considerations

Reference 5 gives a drag coefficient (C_D) of 1.4 for a parachute.[8] However, none of the texts on aerodynamics provided a C_D for a sphere nestling inside a parachute. It was felt that a sphere inside a parachute may act to increase the drag rather than reduce it as might normally be assumed. The simplest way to determine the drag was by actual test, which was done.

Measurement of the tension in the balloon tether at 10 MPH winds with a wind speed meter gave tension readings that varied from 1.5 lbs to 1.7 lbs.

Force due to drag $= C_D \times \frac{1}{2} \rho V^2 \times A$

where V = Velocity in ft/sec

$C_D = 1.4$

$\rho = .002378$ air density at sea level in slugs/ft^3

A = Area exposed = 4.9 sq ft

then $F_D = 1.4 \times \frac{1}{2} \times 0.002378 \times (\frac{5280}{3600} \times 10)^2 \times 4.9 = 1.756$ lbs.

Thus, it appeared that the C_D of 1.4 was slightly high. So it was adjusted to 1.3. For ease of calculation, and to indicate the force in realistic terms, the quantity

$C_D \times \frac{1}{2} (\frac{5280}{3600}) A^2$ = reduces to $0.0033 \times A$, then

$F_D = 0.0033 \times V^2 \times A$, in pounds, or

$F_D = 0.2591\ V^2$, in ounces.

---

[8] Sighard F. Hoerner, Dr. - Ing. Fluid-Dynamic Drag (Theoretical, Experimental and Statistical Information), Published by the Author, 1958.

APPENDIX C (Cont'd)

Table No. 1

Calculation of Performance of Balloon in Winds 0 to 10 MPH

1 Velocity	2 Velocity Squared	3 Constant	4 Area Exposed to Wind	5 Convert Pounds to Ounces	6 Divide by 2	7 Reciprocal of Column 6	8 Tether Angle of Elevation
V	V^2	× .0033	× 4.908	× 16	÷ 2	1/X	α
10	100	.33	1.619	25.91	12.95	.077	4.41
9	81	.2673	1.311	20.99	10.49	.095	5.44
8	64	.2112	1.036	16.58	8.292	0.120	6.87
7	49	.1617	.793	12.6979	6.348	0.157	8.95
6	36	.1188	0.583	9.329	4.664	0.214	12.10
5	25	.0825	0.404	6.478	3.239	0.308	17.15
4	16	.0528	0.259	4.1462	2.0731	0.482	25.7
3	9	.0297	0.145	2.332	1.1661	0.857	40.6
2	4	.0132	0.064	1.036	0.5182	1.92	62.6
1	1	.0033	0.0161	0.2591	0.1295	7.71	82.6
0	0	0	0	0	0	0	0

APPENDIX D

Table No. 3

Calculation of Probability of Detecting Balloon on First Pass of Aircraft

TARGET No.	Description	Area Sq Yds	SLANT & GROUND RANGES (FEET) R_o	D_o	R_1	D_1	M	D_m	R_m	TARGET SQ. MIL SIZE S_1	S_2	$\sqrt{\bar{s}}$
1	8 cu ft spherical balloon	0.538	2121.3	1500	538	-1402	991.3	1402.0	2053.1	1.076	1.1487	1.0546
			4949.7	3500	538	-3558.	2445.4	3458.4	4920.4	0.1976	0.1999	.4458
			28284.2	20000	538	19992	14136.0	19992.0	28278.6	0.0060	0.0060	.0774
2	10 cu ft teardrop balloon	1.003	2121.3	1500	1003	-1115	788.6	1115.3	1869.1	2.006	2.5836	1.515
			4949.7	3500	1003	-3353.2	2371.0	3353.2	4847.1	.3684	.3842	.613
			28284.2	20000	1003	-19974.5	14124.3	19974.3	28266.4	.0113	.0113	.1063

80 Knots x 1.152 = 92.16 MPH

No.	Target Distinctiveness Contrast C	T_o	T_s	P_o	P_m	$\bar{P}$	T_e	Effective Size S_e VSCTE	Probability of Detection on First Pass PTDI	
1	24	Greater	1	1	1	1	1	25.31	0.344	at 1500' altitude
	24	than	1	1	1	1	1	10.70	0.163	at 3500' altitude
	24	5 sec	1	1	1	1	1	1.85	0.030	at 20,000' altitude
2	24	Greater	1	1	1	1	1	36.36	0.455	at 1500' altitude
	24	than	1	1	1	1	1	14.71	0.218	at 3500' altitude
	24	5 sec	1	1	1	1	1	2.551	0.042	at 20,000' altitude

APPENDIX D
(continued)

Definitions of Symbols Used in Calculating Model Values

H	Aircraft altitude (Input variable).
V	Aircraft velocity (Input variable).
A	Target area in square yards (Input variable).
R_o	Closest slant range from flight path to target (Input variable).
D_o	Closest ground range from the line of flight to the target, $=\sqrt{R_o^2 - H^2}$.
R_I	Threshold identification slant range
D_I	Ground range corresponding to the threshold slant range, $=\sqrt{R_I^2 - H^2}$.
M	Ground range at which exposure time is maximum, $= \frac{D_I}{\sqrt{2}}$.
D_M	Maximum ground range at which a target in position D_o can be identified (the distance at which the target first comes into view with this scan pattern), $= D_I$, when $D_o > M$; or, $=\sqrt{D_o^2 + (D_o + 100)^2}$, when $D_o \leq M$.
R_M	Maximum slant range at which the target first comes into view, $=\sqrt{D_M^2 + H^2}$.
$\sqrt{S}$	Square root of average target apparent size, $=\sqrt{\frac{S_1 + S_2}{2}}$.
S_1	Maximum square mil size (apparent target size at closest slant range, R_o), $= A\left(\frac{3000}{R_o}\right)^2$.
S_2	Minimum square mil size (apparent target size at farthest slant range, R_M), $= A\left(\frac{3000}{R_M}\right)^2$.
C	24
T_e	Effective exposure time, $= T_s\overline{P}$.
T_o	Total possible target exposure time, $= \frac{2\sqrt{D_I^2 - D_o^2}}{V}$, when $D_o > M$; or, $= \frac{2\,(D_o + 100)}{V}$, when $D_o \leq M$.
T_s	Effective time score, $= 1$, when $T_o \geq 5$ sec.; or, $=\sqrt{T_o/5}$, when $T_o < 5$ sec.

$\bar{P}$	Average probability of a line of sight from the aircraft along the target path, $= \frac{P_o + P_M}{2}$
P_o	Probability of a line of sight from the aircraft to D_o
P_M	Probability of a line of sight from the aircraft to D_M
S_e	Effective target size exposed, $= \sqrt{\bar{S}}\, CT_e$.
P_{TDI}	Probability of target detection/identification

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